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ENVIRONMENTAL TESTING OF SATELLITE-BORNE INSTRUMENTS

Kunio Hirao

SPACE RADIO PATROL

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INFORMAL SYMPOSIUM ON ARTIFICIAL SATELLITES

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CONTENTS

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ENVIRONMENTAL TESTING OF SATELLITE-BORNE INSTRUMENTS

Kunio Hirao In NASA, Washington Environmental Testing of Satellite-Borne Instruments. Space Radio Patrol Jan. 1964

(Radio Wave Research Institute)

p 1-5 (See X64-12553 07-15)

Satellite instruments need rigorous environmental testing, which does not occur in experiments with ordinary rockets, in particular with our low-acceleration rockets; this is so because satellite instruments must remain long in orbit and are exposed to solar heating, rapid radiative cooling, and so on. /1

The following are environmental tests on instruments designed for mounting in a four-stage high-altitude rocket: The Argo-D-4 (Javelin) -- Honest John, Nike booster, Nike booster and X-248A6. The conditions in this rocket are said to be severe and to approach those in satellites.

Satellite-Borne Instruments

Environmental tests on the Argo-D4, used in fixed-frequency topside sounding:

1. Balance	2. Spin	3. Temperature
4. Humidity	5. Acceleration	6. Shock
7. Vibration	8. Thermal vacuum	9. CG determination
10. Mass moment of inertia		

Actual tests:

1. 60

2. Prototype 715 rpm, 2 min; 150 rpm, 5 min /2

   Flight, payload 700 rpm, 2 min; 120 rpm, 5 min

3. Chamber conditions $25 \pm 10^{\circ}C < 90\%$

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Test: 6 hr at 60°C (after equilibration)

6 hr at -30°C (after equilibration)

Performance checked at 47°C and -5°C after equilibration.

Equilibrium condition: Temperature at center of main body within 1.7°C.

4. Prototype: 95% at 30°C after equilibration; 50-hr check

5. Centrifuge test

Prototype:

Two horizontal axes: 3 G 10% at CG for 3 min

Vertical axis: 50 G -15% to 10% at CG for 3 min

6. Prototype: Dropped 1 inch, twice

7. Vibration test

a) Prototype: sine wave, logarithmic frequency variation, about 2 octave/min

Vertical direction:

cps	min	G (peak)	
5-50	1.6	2.3	Range ± 0.25 inch
50-500	1.6	10.7	
500-2000	1.0	21.0	
2000-3000	0.26	54.0	
3000-5000	0.34	21.0	
	5 min total		

Horizontal direction:

5-50	1.6	0.9	± 0.25 inch
50-500	1.6	2.1	
500-2000	1.0	4.2	
2000-5000	0.6	1.7	

5 min total

b) Combustion resonance: Vertical direction 550-650 cps, ± 86 G, 30 sec

c) Horizontal direction: same, but ± 15 G

d) Random, prototype, vertical direction:

Range, cps	Power Spectral Density (PSD)	G (rms)
5-200	0.12	4.8
200-400	12 db/octave	2.9
400-2000	0.01	4.0

4 minutes

e) Horizontal direction (each of two axes)

5-25	0.60	3.5
25-100	12 db/octave	1.7
100-2000	0.01	4.4

4 min each axis

f) Flight payload (sine wave)

Vertical direction:

cps	min	G(peak)	
5-50	0.8	1.5	(0.5 inch peak to peak)
50-500	0.8	7.1	
500-2000	0.5	14	
2000-3000	0.13	36	
3000-5000	0.17	14	

2.5 min total

Horizontal (two axes)

5-50	0.8	0.6	(0.5 inch peak to peak)
50-500	0.8	1.4	
500-2000	0.5	2.8	
2000-5000	0.3	11.3	

2.5 min total

g) Flight payload, combustion resonance

Vertical:	550-650 cps	56 G peak	15 sec
Horizontal:	550-650 cps	8 G peak	15 sec

h) Flight payload random

Vertical

Range, cps	PSD	G
5-200	0.06	3.4
200-400	12 db/octave	1.7
400-2000	0.005	2.6

Horizontal

5-25	0.30	2.5
25-100	12 db/octave	1.2
100-2000	0.005	3.1

2 min each

8. Prototype: Chamber temperature 25 $\pm$ 10° in flight /5

a) 5×10^{-5} mm Hg (equivalent to 400 000 ft)

Radiant heat source, 47°C for 0.5 hr after equilibration

b) 5×10^{-5} mm Hg, - 5°C for 0.5 hr after equilibration

c) Flight payload: tested at + 37°C and +5°C.

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SPACE RADIO PATROL

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12555 Environmental Testing of Satellite-Borne Instr. (2#) Space Radio Patrol

Author ?

We discussed the basic features of space radio-wave phenomena over a wide frequency range at the first symposium, at which we showed that a satellite carrying several receivers (VLF to HF) and launched into an orbit of high eccentricity can give a clear picture of the electron-density distribution, of the propagation characteristics for radio waves of external origin, and of the specific features of waves emitted within the plasma. Here we examine the US satellite program and some related projects already in operation. Some particular features of our space radio patrol are also considered. /6

AUTHOR

Jan. 1964 p 6-14 refs (See X64-12553 07-15)

1. Radio Research in the US Satellite Program

Table 1 collects US satellite observations reported in 1963; it shows the frequency band and the individuals responsible. In addition, parts of the Ariel II program (UK) and US-Australia joint program have been included. The last is intended for operation from 1963 onwards; in it, noise is received on 8 channels, in each of which the frequency is swept through 1/4 of the central frequency (the full range covers the VLF and ULF bands).

The range 0.01 cps to 4 Mc (terrestrial magnetic variations to cosmic radio noise) is covered by the first EGO and POGO programs in several broad bands, the object being to observe electromagnetic wave phenomena. There are certain differences between bands depending on whether spot frequencies or wide-range sweep is used, but the only substantial gap occurs in the range 100 to 700 kc. /7

Our space radio patrol is concerned particularly with wave phenomena in the range 1 kc to 10 Mc (spot frequencies 1,3, 10, 30, 100, 300, 1000 and 3000 kc); our observations may therefore by chance overlap those of others, except at 100 and 300 kc. This can give independent confirmation; the patrol method of combining VLF and HF has not been used before.

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2. Examples of Methods

Some very interesting results have already been reported for radio wave phenomena in the upper atmosphere, although only the range 0.75 to 4 Mc is covered, as by Molozzi et al. [1] and Chapman [2] (Topside project) on cosmic noise. Walsh, Haddock, and Shulte more recently (June 1963) reported to COSPAR on results from a rocket fired on September 22, 1962; cosmic radio noise was recorded at spot frequencies of 0.75, 1.225, and 20 Mc as part of the Topside program at heights up to 1700 km. The following points are of particular interest here: /8

I) Radio noise was very slight for $f_0 > f > f_H$ (or $f_0 < f < f_H$), in which f_0 is the plasma frequency and f_H the gyro frequency.

II) Accuracy was improved by measurement of antenna impedance and correction of receiver gain.

Correction for the dielectric constant was needed because only whip antennas were used. The impedance was measured at 12-second intervals; the data gave the electron density at the corresponding point. This provides a means of plotting X $(= \omega_p^2/\omega^2)$ and Y $(= \omega_H^2/\omega^2)$ as functions of the space coordinates. For 750 kc (the object of discussion in the previous symposium) $f_0 > f > f_H$ ($f_H > f > f_0$ is possible, as is the case in the present instance) and the region was quiet; cosmic radio noise was detected just beyond f_H. The impedance variation of a whip antenna used to measure electron densities can be very large, in which case it is necessary to correct the wave measurements; it is also important to adjust the gain and so determine the base noise level. Figure 1 shows the method used in block-diagram form. The following measurements were made:

0-6 sec, cosmic radio noise	6-8 sec, receiver zero point correction
8-10 sec, receiver gain correction	10-12 sec, antenna capacitance measurement

3. Space Radio Patrol Methods (2 or 3 Projects)

3.1 Antenna

We showed in our previous paper that it is theoretically possible to deduce the plasma frequency in the terrestrial magnetic field, the spatial variation in the cyclotron frequency, and the spectrum and propagation characteristics of radio noise over a broad frequency range by recording the strength and direction of arrival at 1, 3, 10, ..., 1000, and 3000 kc. The first problem here concerns the choice of antenna. /9

A loop antenna has the advantage of indicating the direction of arrival; moreover, there is no need to correct for impedance variations arising from the electron density. Furthermore, an antenna of the size that can be mounted on a satellite has a very low effective height; radio noise readily detected with a whip antenna may not be detectable with the loop.

The effective height (meters) of a loop antenna is:

$$H_{el} = \frac{2\pi NS}{\lambda} \tag{1}$$

in which N is number of turns, S is area of a turn (m^2), and λ is wavelength (m). A whip antenna has $\lambda \gg l$ (l = length), and

$$H_{ew} = l/2 \tag{2}$$

(in meters). For $S = 0.1$, $l = 1$, and $f = 30$ kc, a loop would have to have over 1000 turns (even if a transformer ratio of 10 could be used) to give the same effective height. Moreover, the use of a step-up transformer would result in a very poor Q, so the actual performance would be well below that of a whip. This adverse feature becomes more pronounced towards lower frequencies, so it is impossible to use a loop for all frequencies. /10

This means that a whip antenna must be used together with a loop; but it has $l \ll \lambda$ and is generally capacitative, being influenced by the electron density and the gyro frequency. The impedance must therefore be measured, but the electron density so found does not indicate the direction of the antenna. In fact, the antenna is unable to measure the plasma frequency in addition.

The Adcock antenna falls between the loop and the whip. It resembles a loop in being directional and of low efficiency $H_e = {}^{l}H_e/\lambda$, in which H_e is the effective height of a whip antenna); it resembles a whip in that its impedance varies with the dielectric constant. It is clear from the paper at the last symposium that this antenna is to be rejected; only the whip and loop should be used.

Intensity and direction alone cannot give satisfactory results; better ones are to be expected from combining impedance measurement with the use of loop and whip. The impedance is measured when the radio noise is not being measured; alternatively, a gyro plasma probe we are developing could be used (this is an impedance probe of frequency- /11
sweep type). Table 2 shows the antennas to be used at each frequency.

3.2 Telemetry

The method of Haddock et al. is used above 100 kc; the noise generator is switched to the receiver input, and the level of the detected noise is transmitted. If the input is zero, it is necessary to send a switching signal. The same information can be obtained without the use of complex equipment such as a current-measuring instrument (recorder). Such instruments are meant for routine work and are unsuitable for use in satellites.

The actual waveform can be transmitted without switching to a standard level in the telemetry channel at frequencies below 30 kc.

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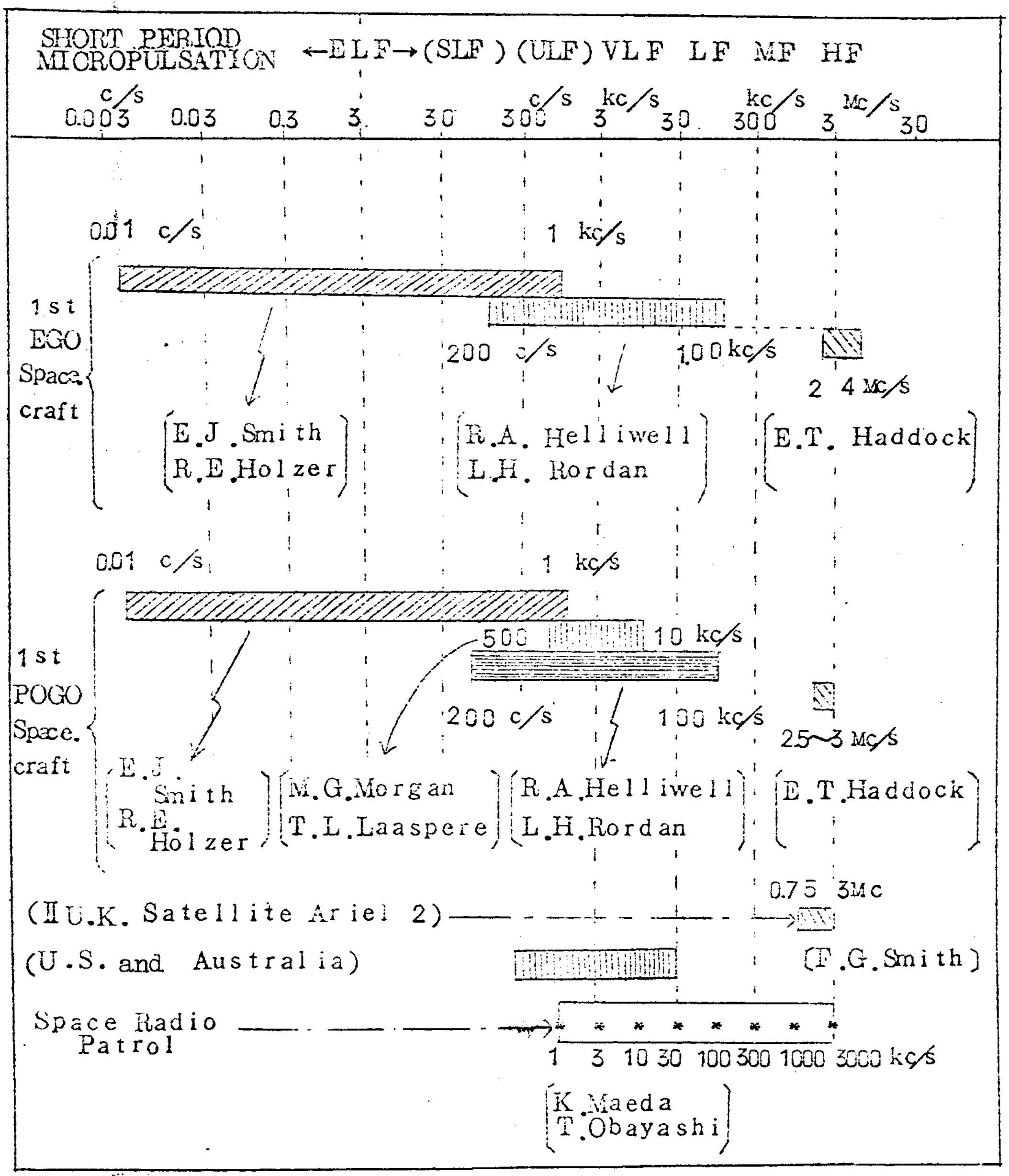
1. Molozzi, A. R., Franklin, C. A. and Tyas, J. P. I. Nature, 190, 616,1961.
2. Chapman, J. H. Space Research II, Proceedings of the Second International Science Symposium, Florence. p. 597, 1961.
3. Cartwright, D. G. Annual Report of Commonwealth Scientific and Industrial Res. Organization. p. 12,1962.

TABLE 1

/12



[cont'd. next page]

[Table 1 continued]

*Spot frequencies

Note: The VLF-ELF boundary varies from one author to another; the following is from Aaron, "The Radio Noise Spectrum," for the region below VLF:

ELF 0.3-30 cps

SLF 30-300 cps

ULF 300-3000 cps

TABLE 2

f, kc	1, 3, 10, 30	100, 300	1000, 3000
Antenna	Whip, loop as supplement	Loop, whip as supplement	Loop
Remarks	Impedance to be measured over wide range		

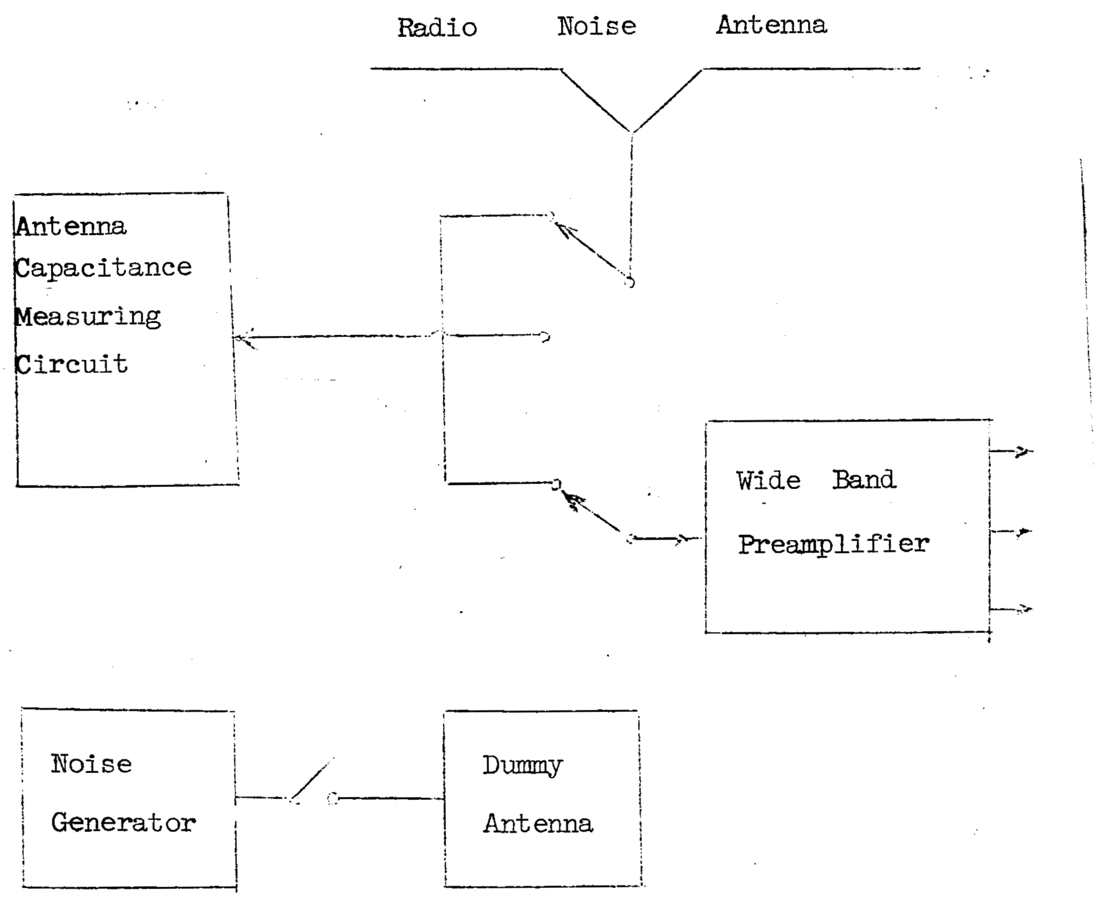


Fig. 1. Antenna capacitance measurement, receiver gain, and method of base point correction (Haddock).

APPENDIX

First EGO Spacecraft (20 projects) /15

8. Fluctuations in vector magnetic field in frequency range 0.01 to 1000 c/s using triaxial search coil magnetometer.

   E. J. Smith, R. E. Holzer, Jet Propulsion Lab.

   U. C. L. A.

14. VLF noise and propagation at frequencies of 200 to 100,000 c/s.

   R. A. Helliwell, L. H. Rordan, Stanford University.

15. Radio astronomy in frequency band 2 to 4 Mc/s, primarily to measure the dynamic radio spectra of solar bursts.

   F. T. Haddock, University of Michigan

First POGO Spacecraft (17 projects)

1. Radio astronomy measurements of galactic emission at 2.5 and 3.0 Mc/s.

   F. T. Haddock, University of Michigan

2. VLF measurements of terrestrial and other emissions in the frequency range, 0.2 to 100 kc.

   R. A. Helliwell, Stanford University

3. VLF terrestrial and other emissions at 0.5 to 10 kc.

   M. G. Morgan, T. L. Laaspere, Dartmouth College

4. Relationship between VLF emissions and high-energy electron bunches from 5 to 100 Kev.

J. A. Winckler, University of Minnesota

R. M. Gallet, National Bureau of Standards

5. Fluctuations in vector magnetic field in frequency range 0.01 to 1000 c/s using triaxial search coil magnetometer.

E. J. Smith, R. E. Holzer, Jet Propulsion Lab.

U. C. L. A.

Second OSO Spacecraft (9 projects) /16

Third OSO Spacecraft (8 projects)

First Interplanetary Monitoring Probe (7 projects)

Second U. K. Satellite (ARIEL 2)

A. A galactic radio noise study in the frequency range between 0.75 to 3.0 Mc/s and exploration of the upper atmosphere.

F. G. Smith, The University of Cambridge

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